2010 International Workshop on Extreme Ultraviolet Sources
November 13-15, 2010
University College Dublin ▪ Dublin, Ireland

Development of Multilayer Spectral Purity Filters for EUVL Tools

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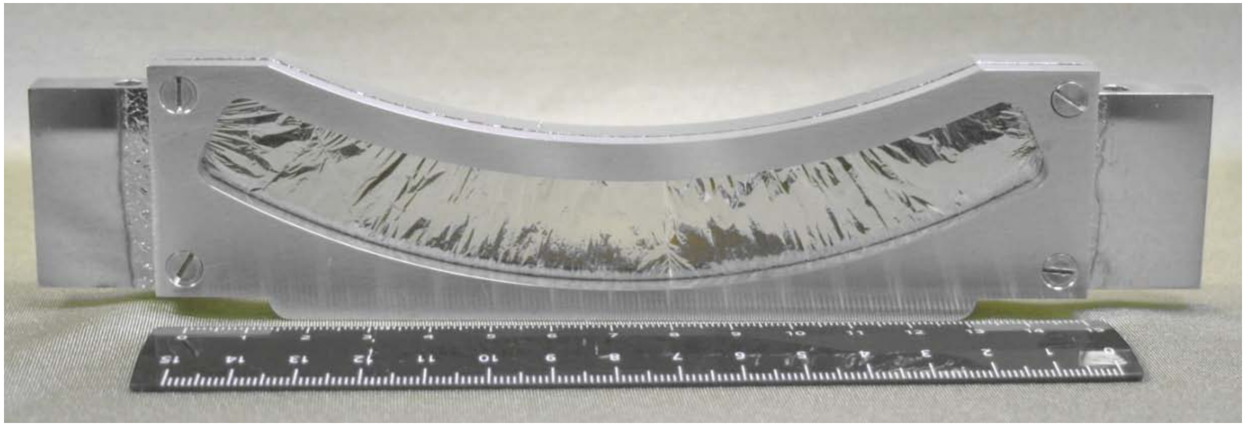
Agenda

- Previous results with structures containing Zr, Si, $ZrSi_2$
- Towards requirements for HVM tools
- Introducing Mo, $MoSi_2$ to retard oxidation effects
- Tests with high power density loads
- Results of high temperature exposures
- Estimation of tensile strength
- Fabrication of pilot samples with large clear aperture
- Conclusions, further tasks

Zr/Si multilayer structures (2004-2006)

- Suppression of DUV at <1.5 W/cm^2 absorbed
- 55 nm, T_{IB} = 76%, T_{DUV} = 0.2 ÷ 1%,
- <600 °C, T_{IB} drop 3-4% after few hours
- Large dimensions

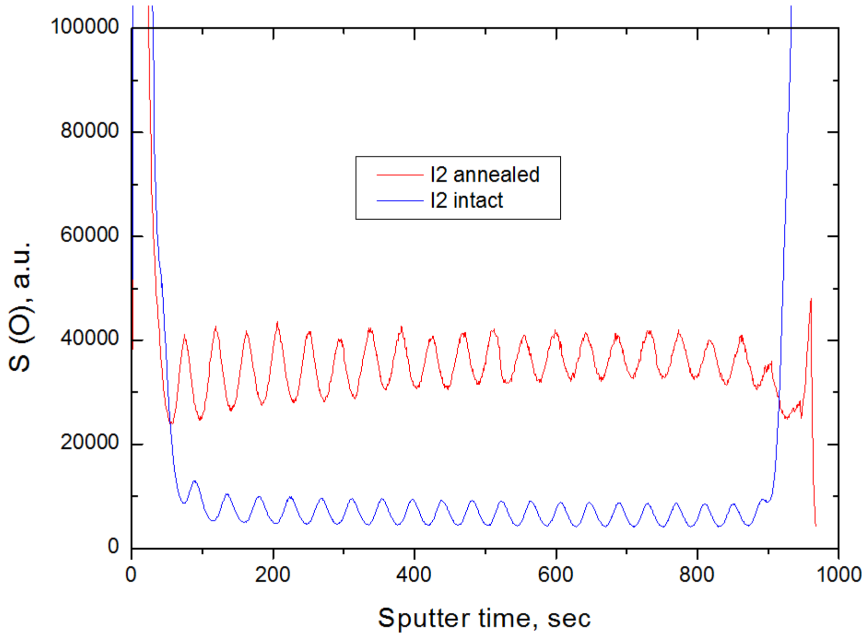
SPF fabricated for Alpha Demo Tool (2006)



$Zr/ZrSi_2$ multilayer structures (2008)

- Suppression of DUV and 10.6 μm at 3 W/cm^2 absorbed
- 60 nm, T_{IB} = 70%, T_{DUV} = 0.2 ÷ 1%, $T_{10.6}$ = <2%, $R_{10.6}$ → 80%
- <700 °C, T_{IB} drop 3-4% after 6-8 hours,

  associated with high-temperature oxidation



Pre- and post-exposure SIMS analysis revealed accumulation of oxygen, correlated with $ZrSi_2$ location

Towards requirements for HVM tools

We must expect:

- **Further essential increase of irradiation power, leading to SPF temperatures above 1000 °C**
- **Required stability/lifetime – on a scale of months**

Major issues:

- high-temperature oxidation

- mechanical stress and repetitive deformation caused by pulsed irradiation and power modulation

Introducing structures with Mo, $MoSi_2$ to retard oxidation effects

$MoSi_2$ cup | Mo-$ZrSi_2$ multilayer core | $MoSi_2$ cup

Ductile padding layers of $ZrSi_2$ enable lifting process, resistance to deformations and high IB transmission

Spectral data for a 53.5 nm sample:

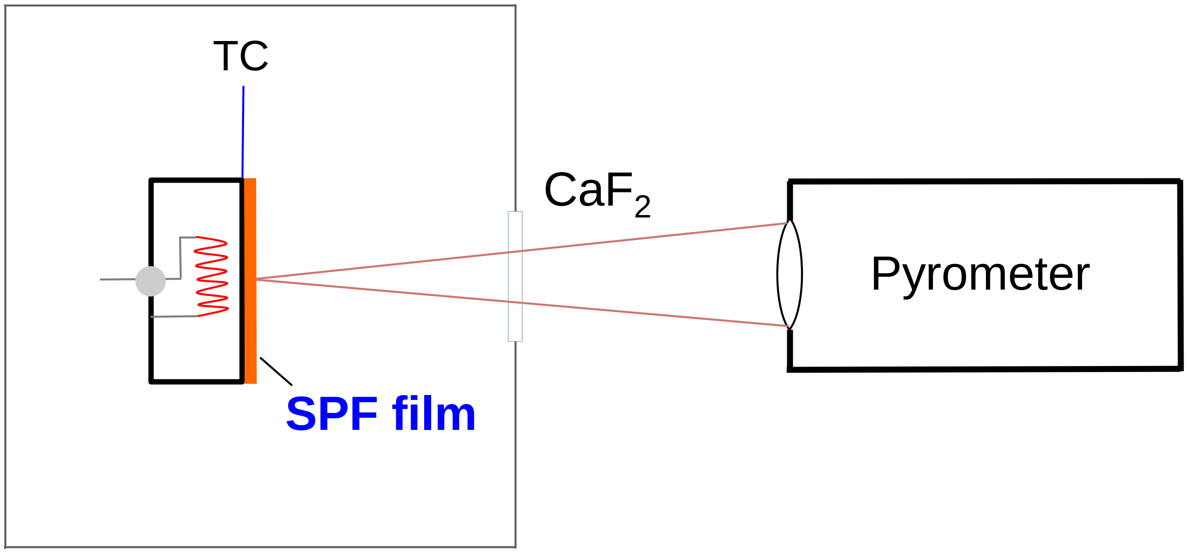
$R_{10.6}$, %	$T_{10.6}$, %	T_{633}, %	$T_{13.5}$, %
83.2	0.84	0.72	71.4

Tests with high power density loads

- Heating with CO_2 laser beam of samples at 10^{-7} mbar (H_2O)
- Power density: incoming <40 W/cm^2, absorbed <8 W/cm^2
- Temperature range 700 ÷ 1100 °C (at central point)
- Exposure time 17-20 hours (to measure IB transmission drop)
- Power modulation by laser beam interruption at a few Hz
- Temperature recording by pyrometer, calibrated on thermocouple in full range
- Pre- and post-exposure transmission measurements (IB, DUV, 10.6 μm); reflectivity for 10.6 μm on supported films
- Pre- and post-exposure SIMS analysis

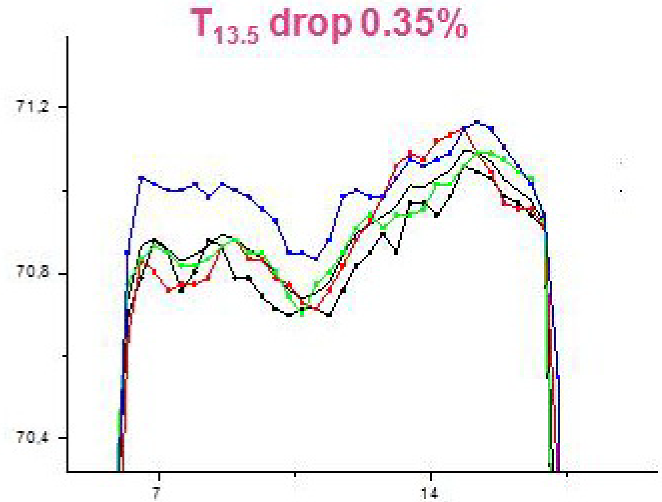
Pyrometer calibration

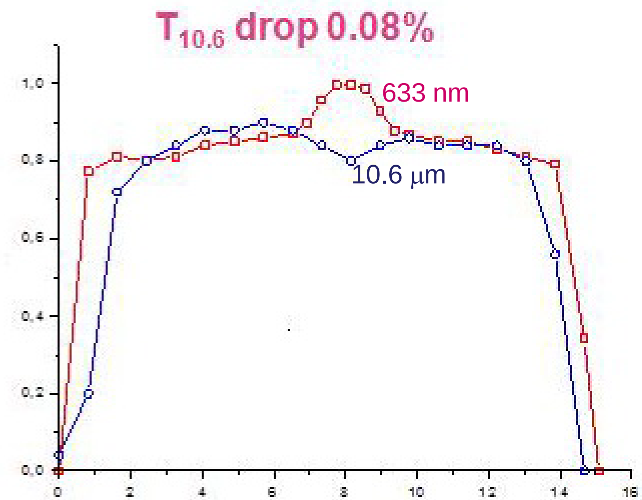
(determination of film emissivity)



Material emissivity value in pyrometer settings adjusted to get reading coinciding with that of the thermocouple

Results of high temperature exposures





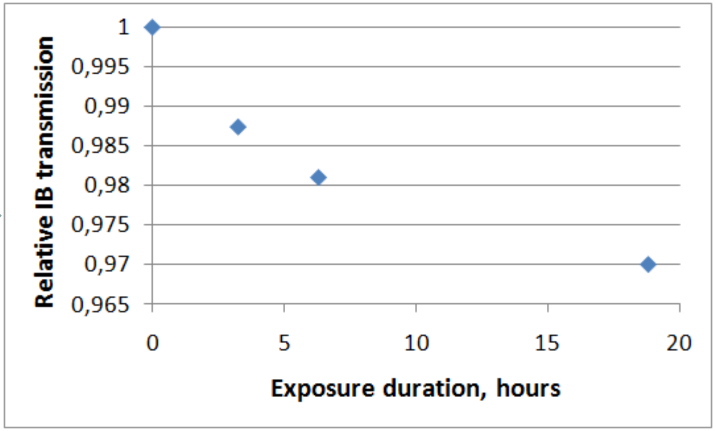
Exposure facts:

900 °C (4.3 W/cm²)

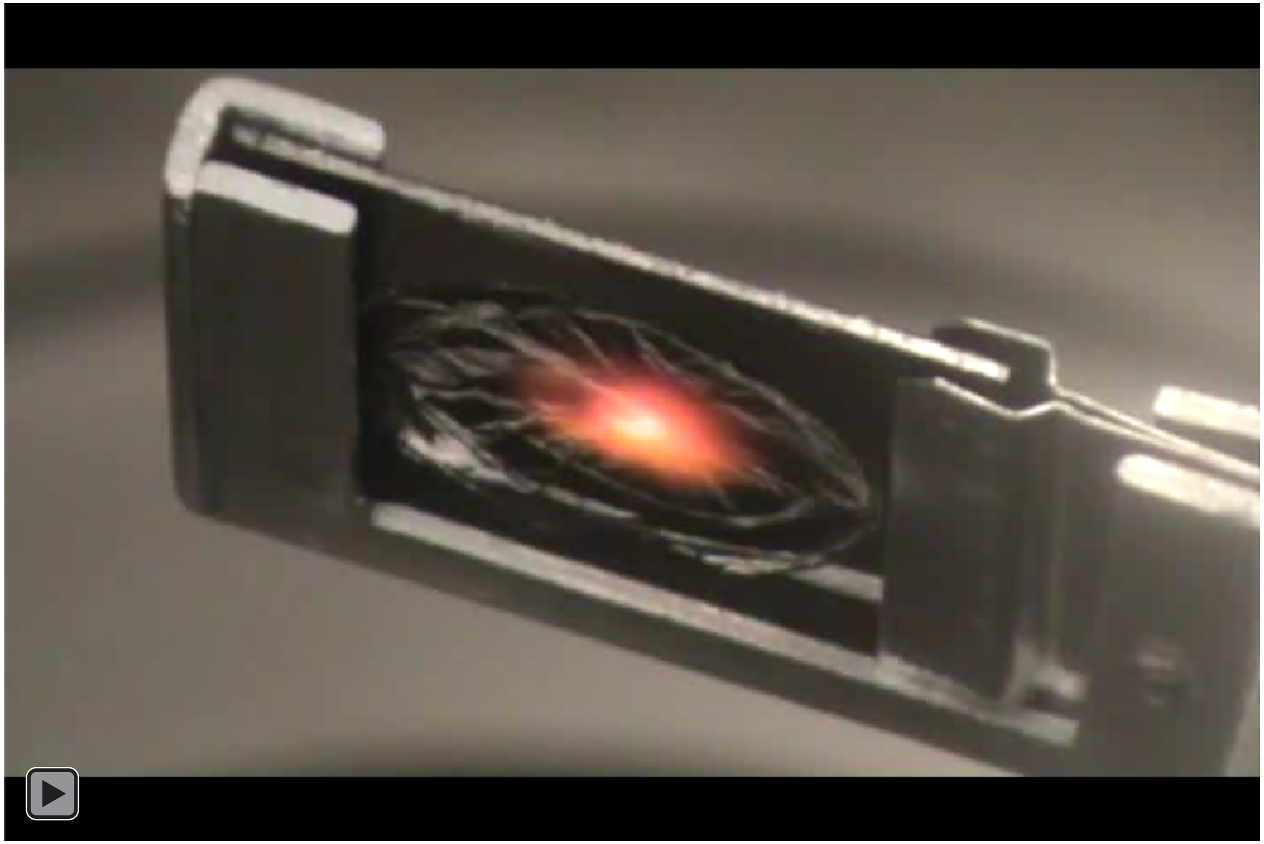
0,35% drop of IB transmission after 17 hours

950-970 °C (5 W/cm²)

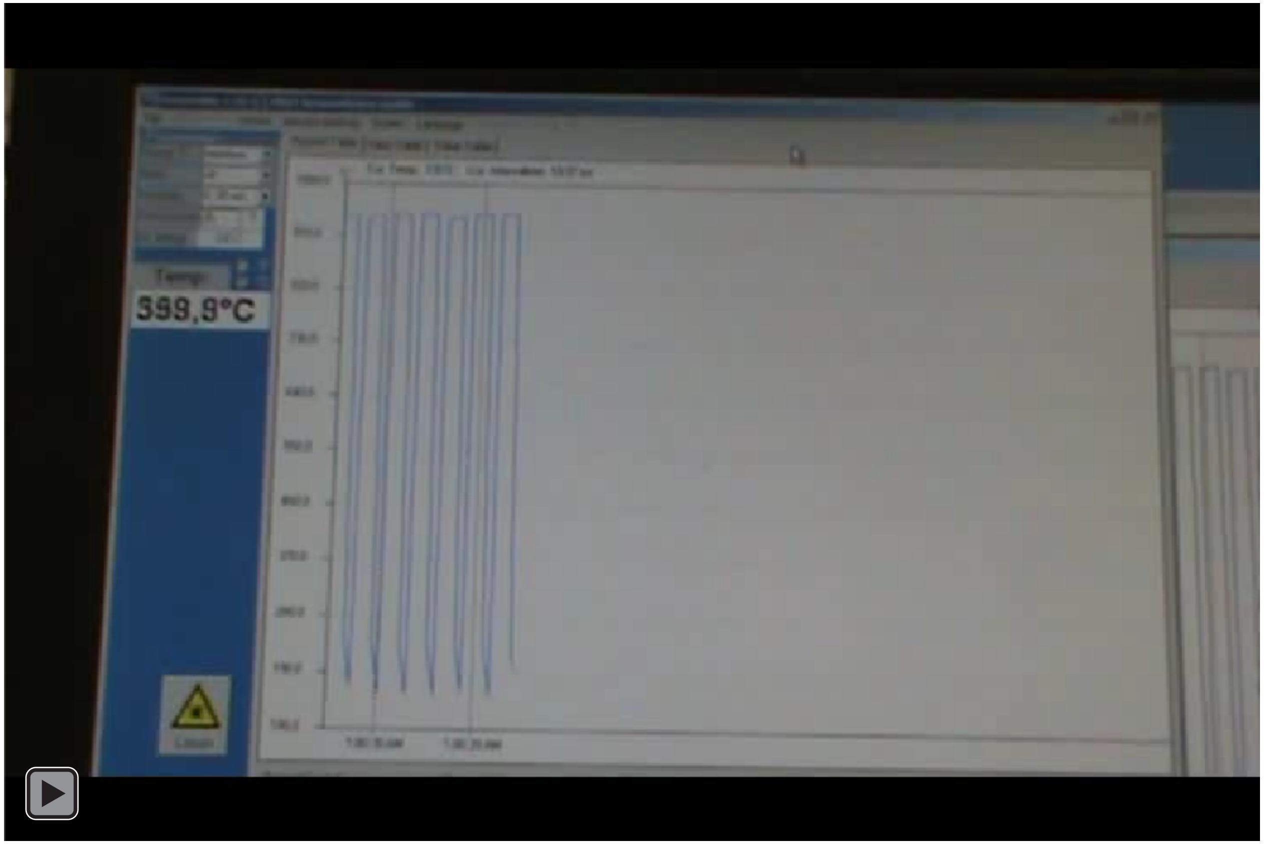
2% drop of IB transmission after 19 hours



Modulated irradiation of SPF sample

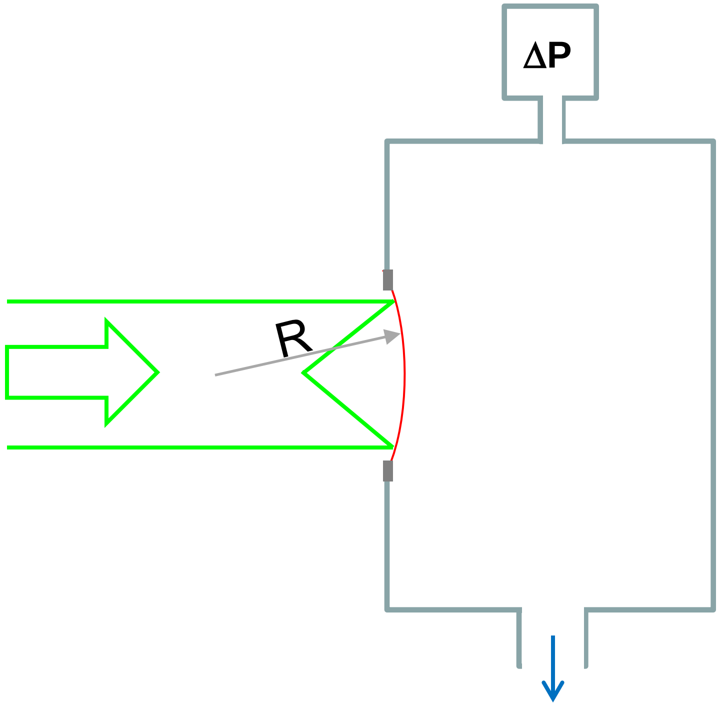


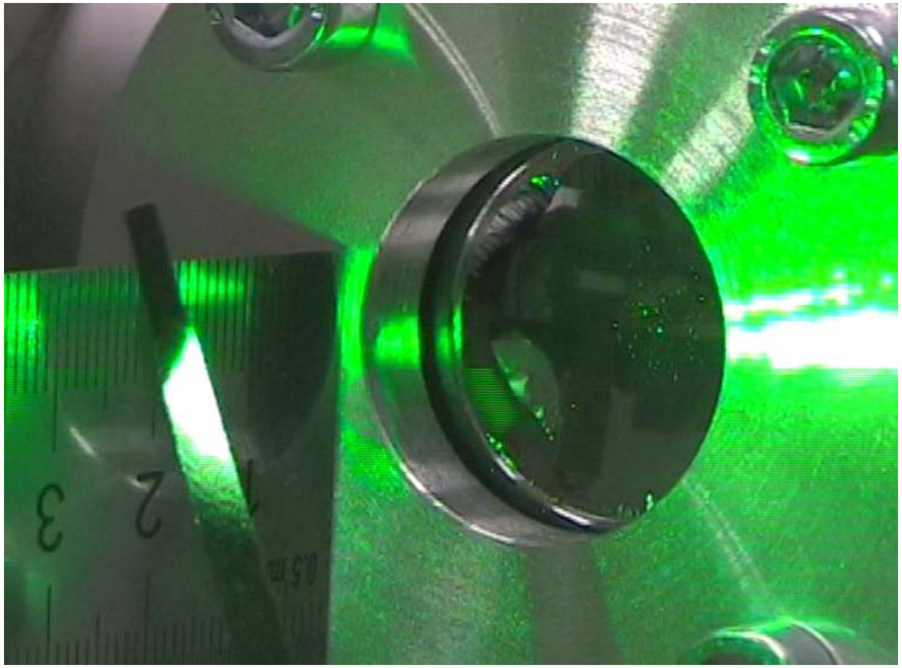
Recorded temperature variation



Estimation of film tensile strength

from pressure differential and curvature

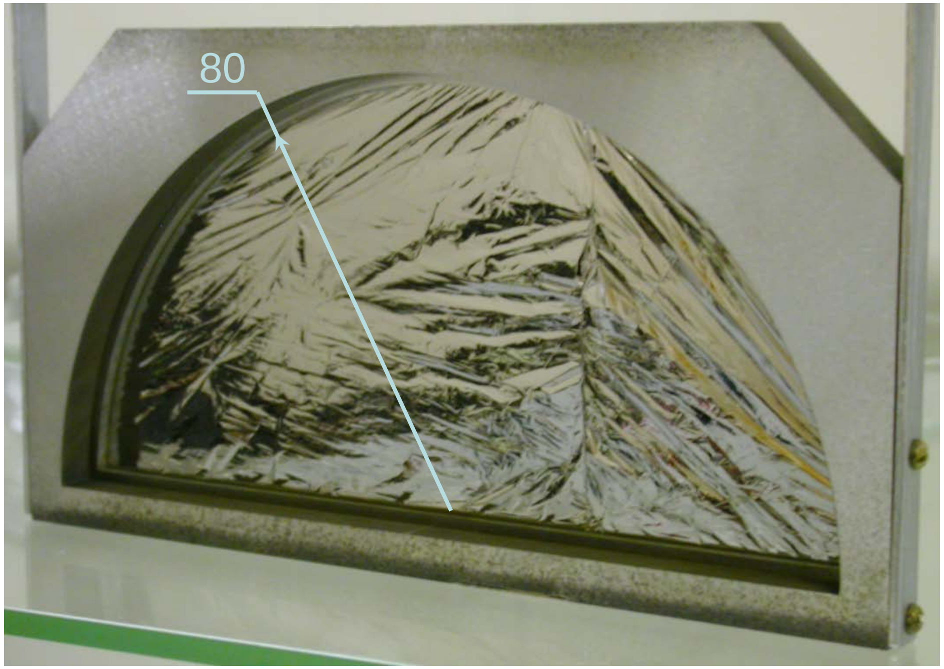




$$\sigma = \Delta P \times R / 2h \quad \Longrightarrow \quad 1 \div 2 \text{ GPa}$$

SPFs with large clear apertures

Pilot 90 nm SPF film on technological frame



Apertures above 200 mm are feasible

Conclusion

- **Recent progress in SPF parameters, in particular anti-oxidation features, is not sufficient for expected HVM conditions**

Priority tasks

- **Search for padding layers with ultimate chemical and mechanical characteristics**
- **Providing experimental possibilities for scalable tests of SPF samples under intensified oxidation and mechanical load**

Acknowledgment

To V. Banine, A. Yakunin – for constant stimulating interest and detailed discussions of HVM related SPF issues